

# Papaya

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**Scientific Name and Introduction:** Papaya, papaw or paw paw (*Carica papaya* L.) is cultivated throughout the tropics for its fruit (Nakasone, 1986). Fruit are eaten green or ripe, in salads or fresh. The related Ecuadorian babaco (*C. pentagonia*) is also eaten fresh.

Fruit are pyriform (pear-shaped), spherical or cylindrical. The pyriform, hermaphroditic fruit is the most common in commerce. These belong to the 'Solo' group and includes the cultivars Kapoho, Rainbow, Sunup, Sunrise, and Sunset weighing from 300 to 700 g (10 to 25 oz). Sizes of other varieties range from 200 g to 10 kg (0.4 to 22 lbs), with flesh thickness from 1.5 to 4 mm (0.06 to 0.16 in). Flesh is greenish-white in immature fruit to pale orange-yellow, salmon pink, or red depending on cultivar when ripe.

**Quality Characteristics and Criteria:** Size, shape, smooth skin, and absence of blemishes are major quality characteristics. Consumers in Western countries also prefer fruit without a heavy musky, sweaty odor found in some Southeast Asian cvs. Small dry brown-black "freckles" on the skin are non-pathogenic and do not detract from ripening or flavor (Reyes and Paull, 1994).

**Horticultural Maturity Indices:** In Hawaii, minimum grade standard requires 11.5% SSC (Anon, 1990). So, fruit should have started ripening before harvest, as indicated by some skin yellowing (Akamine and Goo, 1971). Less mature fruit are lower in sugar and ripen poorly.

**Grades, Sizes and Packaging:** The most common package size is a 4.5 kg (10 lb) carton, larger 10 kg (22 lb) cartons are also used. Cartons from areas requiring insect disinfestation are fully sealed to meet regulatory requirements, while fruit from other areas can be in open topped cartons. Count size ranges from 6 to 18, depending upon fruit and carton size. Fruit are marketed as color break,  $\frac{1}{4}$ ,  $\frac{1}{2}$ , and  $\frac{3}{4}$  ripe, and are normally ready to eat when there is 75% or more skin color. Foam mesh sleeves, foam padding on the bottom of cartons, or paper wrapping prevent abrasion injury that is a major problem in fruit still having green areas of skin (Quintana and Paull, 1993).

**Pre-cooling Conditions:** Room and forced-air cooling are commonly used. Hydro-cooling is possible. However, rapid cooling after insect disinfestation treatments can lead to skin scalding.

**Optimum Storage Conditions:** Store from 7 to 13 °C (45 to 55 °F) with 90 to 95% RH. At 7 to 10 °C (45 to 50 °F), storage-life is limited by chilling injury, while at 10 to 13 °C (50 to 55 °F) ripening occurs slowly (Chen and Paull, 1986). Papaya fruit at color-turning (break) stage can be stored at 7 °C (45 °F) for 14 days and will ripen normally when transferred to room temperature (Thompson and Lee, 1971; Chen and Paull, 1986). Ripe, full color, fruit can be held for > 1 week at 1 to 3 °C (33.8 to 37.4 °F).

**Controlled Atmospheres (CA) Consideration:** Shelf-life extension of 1 to 1.5 days was obtained when papaya were stored at 12 °C (54 °F) in 1 to 1.5% O<sub>2</sub> for 6 days (Akamine and Goo, 1969). Low O<sub>2</sub> (1 to 5%), with or without high CO<sub>2</sub> (2 to 10%), reduces decay (Hatton and Reeder, 1969) and delays ripening (Akamine 1959; Chen and Paull, 1986). High CO<sub>2</sub> (30%) adversely affected internal color, aroma and flavor, while there is no residual effect of 10% CO<sub>2</sub> on decay control, though skin degreening is delayed.

At 10 °C (50 °F), fruit can be stored for 36 days in 8% CO<sub>2</sub>+ 3% O<sub>2</sub> and still have 5 days at 25 °C (77 °F) for retail (Cenci et al., 1997). Ethylene removal prior to storage has shown variable results

(Nazeeb and Broughton, 1978). CA recommendations are in the range 2 to 5% O<sub>2</sub> plus 5 to 8% CO<sub>2</sub>. However, no commercial use has so far been reported (Yahia, 1998). Fruit stored at 10 °C (50 °F), 98% RH and low pressure of 20 mm Hg, ripened more slowly than fruit at normal atmospheric pressure. Low pressure storage appears to suppress disease development (Alvarez, 1980; Alvarez and Chau, 1983).

**Retail Outlet Display Considerations:** The optimum temperature for fruit ripening is 22.5 to 27.5 °C (73 to 82 °F), with fruit taking 10 to 16 days to reach full skin yellowing from the color-break stage (An and Paull, 1990). Severe weight loss and external abnormalities become significant at temperatures higher than 27.5 °C (82 °F). Display temperatures should not be less than 10 °C (50 °F) if not fully ripe. Fully ripe fruit at the edible stage can be held at 1 to 3 °C (34 to 37 °F). Fruit should not be stacked more than 2 or 3 deep in racks, and wicker baskets with uneven bottoms and sides should be avoided, or at least a layer of protection placed between racks and fruit (Paull et al., 1997). Loss of about 8% of weight from color break produces rubbery, low-gloss, unmarketable fruit (Paull and Chen, 1989). Diseased and bruised fruit should be removed from display and used immediately, if possible, in salads or mixed fruit cocktails. Do not mist.

**Chilling Sensitivity:** Chilling injury symptoms include skin scald, hard lumps in the pulp around vascular bundles and water soaking of flesh (Thompson and Lee, 1971; El-Tomi et al., 1974; Chen and Paull, 1986). Fruit become progressively less susceptible to chilling stress as they ripen (Chen and Paull, 1986). Symptoms of chilling injury occur after 14 days at 5 °C (41°F) for mature green fruit and 21 days for 60% yellow fruit. Skin scald can be induced in color-break fruit after chilling at 1 °C (34 °F) for 24 h. At a 7 °C (45 °F) storage temperature for 14 days, storage decay is less than when fruit are held at 12 to 13 °C (54 to 55 °F) (Arisumi, 1956; El-Tomi et al., 1974).

**Ethylene Production and Sensitivity:** Ethylene rates in ripening fruit are 6 to 10 µL kg<sup>-1</sup> h<sup>-1</sup> (Paull and Chen, 1983; Paull, 1993). Ethylene-treated papayas ripen faster and more uniformly in terms of skin degreening, softening and flesh color (An and Paull, 1990). Since papaya ripen from the inside outwards, the effect of ethylene treatment is to accelerate the rate of ripening of the mesocarp tissue nearer the skin that has not started to soften. Ethylene is not recommended commercially, as rapid softening severely limits available marketing time (An and Paull, 1990).

**Respiration Rates:** Papaya are climacteric and begin to yellow from the blossom end (Akamine, 1966).

Temperature	mg CO <sub>2</sub> kg <sup>-1</sup> h <sup>-1</sup>
5 °C	4 to 6
15 °C	15 to 22
20 °C - color break	9 to 18
20 °C - ripe	70 to 90

To get mL kg<sup>-1</sup> h<sup>-1</sup>, divide the mg kg<sup>-1</sup> h<sup>-1</sup> rate by 2.0 at 0 °C (32 °F), 1.9 at 10 °C (50 °F), and 1.8 at 20 °C (68 °F). To calculate heat production, multiply mg kg<sup>-1</sup> h<sup>-1</sup> by 220 to get BTU per ton per day or by 61 to get kcal per metric ton per day.

**Physiological Disorders:** There are a number of non-pathological disorders seen in marketed fruit (Paull et al., 1997). The disorders include the following:

*Green slightly sunken areas* on ripe yellow fruit are due to abrasion injury that occurs when fruit were still green (Quintana and Paull, 1993).

*Unightly skin freckles* (small brown slightly raised areas) that are more common on the side of the fruit exposed to the sun and is seasonal, occurring when rainfall and low temperatures occur 2 mo before harvest (Reyes and Paull, 1994). This disorder is non-pathogenic and does not influence ripening or flavor.

*Sun scald*, a dark olive brown discoloration occurs on fruit developing on trees with very sparse foliage, on trees that are leaning over, with fruit directly exposed to the sun and where harvested fruit are left exposed to the sun.

*Blossom end defect* can be severe at some times of the year (Zee et al., 1989). The disorder leaves an open channel at the blossom end to the fruit seed cavity. Fruit with this disorder are prone to bacterial diseases in the fruit seed cavity before harvest.

*Hard lumps in the flesh* occur infrequently in otherwise ripe, non-heat-treated fruit (Magalona, 1963; Cavaletto, 1989). The lumps are thought to be associated with insect injury, disease or other foreign material in the flesh. The condition can also occur in heat-treated fruit.

*Premature ripe fruit*, referred to as "soft fruit" is related to low fruit calcium. The condition is more common following periods of heavy rainfall, 2 to 3 mo before harvest, at the start of the final phase of fruit growth (Qiu et al., 1995).

*Intra-ovarian ovaries* are common in some strains of papaya (Nakasone and Arkle, 1971). These ovaries occur as a proliferation of tissue in the seed cavity and can be a thread-like appendage, to round or elongated structures of various sizes and shapes. A few fill the entire seed cavity of the fruit and have their own seed cavity.

*Sunken dry brownish-grey areas* caused by mites feeding on skin during early fruit growth. The red and black mite (*Brevipalpus phoenicis* [Geijskes]) generally causes this damage in Hawaii.

**Postharvest Pathology:** The major postharvest diseases are anthracnose and stem end rot. Postharvest diseases, especially anthracnose, become a problem when fruit have 25% or more skin yellowing (Wardlaw et al., 1939; Alvarez and Nishijima, 1987). Papaya diseases greatly increase in severity and incidence following 4 weeks storage at 10 °C (50 °F). Mechanical injury and chilling injury can enhance development of postharvest disease incidence (Somner and Mitchell, 1978; Alvarez and Nishijima, 1987; Nishijima et al., 1990). *Rhizopus* requires breaks in the cuticle for the disease to occur (Nishijima et al., 1990). Cuticle disruption occurs as latex vessels break down, when the fruit is 40 to 60% yellow (Paull and Chen, 1989). Fruit fly punctures can also increase *Rhizopus* rot (Hunter and Buddenhagen, 1972), as can mechanical injuries and lesions caused by fungi such as anthracnose and *Cercospora* black spot (Nishijima et al., 1990). Postharvest diseases are effectively controlled by hot water at 49 °C (120 °F) for 20 min (Akamine and Arisumi, 1953; Glazener et al., 1984; Couey et al. 1984) and fungicide treatment (Couey and Farias, 1979).

**Quarantine Issues:** Fruit fly infestation becomes a problem with papayas after fruit have 25% skin yellowing (Seo et al., 1982). The damage caused by fruit flies include small surface blemishes, destruction of the edible flesh and spoilage from decay. Heat treatments and irradiation are used to achieve fruit fly disinfection (Couey, 1989; Paull, 1990; Armstrong 1994). Occasionally, heat treatment can cause internal injury and scald (Paull, 1995), limits postharvest life, and reduces quality (Paull, 1990). Papaya can tolerate insecticidal atmospheres (0.17 to 0.35% O<sub>2</sub>, balance N<sub>2</sub>) at 20 °C (68 °F) for up to 5 days (Yahia et al., 1989), although its disinfection potential has not been shown.

**Suitability as Fresh-cut Product:** Fruit are prepared as de-seeded, halved fruit, slices and chunks. Fresh-cut products made from 60 to 80% yellow-skinned fruit, over-wrapped with plastic film can be held for up to 3 weeks at 0 to 4 °C (32 to 39 °F) (Paull and Chen, 1997). Powrie et al. (1990) patented a procedure where pieces dipped in citric acid held in multi-layer bags with 15 to 20% O<sub>2</sub> and 3% helium had little loss in taste and texture after 16 weeks at 1 °C (34 °F).

**Special Considerations:** None

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